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STAT

ELECTRONIC MACHINE FOR CENTRALIZED CONTROL

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## ELECTRONIC MACHINE FOR CENTRALIZED CONTROL

Priborostroyeniye [Instrument  
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B. M. Yakobson

Many Russian organizations are engaged at the present time in the development of new systems of centralized control for manufacturing processes. Much attention is being paid to this problem also by many leading instrument-building firms abroad.

The need for such systems has arisen as the result of the development of instrumental means for control of modern complicated technological processes in the chemical, petroleum, rubber, and other branches of the industry.

So far, the use of a control system with indicating and recording instruments has involved, as an essential part, the participation of an operator, who gathers the necessary information and effects in some measure the necessary (inverse) action on the course of the process.

Since the increased number of controlled parameters and measurement points requires, in many cases, the use of a large number of control instruments, the speed and accuracy of the action by the operator becomes a limiting factor for the operation of a control system, and of regulation as a whole. This circumstance has been one of the causes for the development of two characteristic trends in modern control engineering:

(1) An ever increasing use of closed-loop systems of automatic control, encompassing groups of parameters and reducing the need for control instruments.

(2) The development of means of control that facilitate to a maximum the operator's choice and use of the necessary information. Such means include graphic panels, mimic buses, and, on the highest level, electronic machines for centralized control.

Both above trends are closely related with each other and should lead in the final analysis to the creation of centralized systems for control and regulation on the basis of an extensive utilization of the accomplishments in the automatic computing technology.

Centralized control machines are characterized, first, by the use of so-called method of multiple control, connected with the use of switching (run-through) devices, and second, by the conversion of the information arriving from the transducers into numerical form.

The use of sampling devices is the structural base that insures effectiveness and advantages of control machine, for it permits a many-fold reduction in the number of elements of the system (signal amplifiers, measurement systems, sources of electric quantities), to reduce the extent of communication, etc.

The changeover to numerical form of information is necessitated by many considerations, including the tendency for insuring maximum rapid understanding of the information by the operator, elimination of errors due to the reading values on the scales and diagrams of the instruments, and convenience in transmission, transformation, and storage of the information inside of the machine with minimum distortion.

The choice of the principal scheme and the construction of the machine are determined in many cases by specific technical requirements, the principal of which are: the number of controlled points, speed, and accuracy. The satisfaction of these requirements must be accompanied by insuring reliability of the machine, maximum simplicity in its attendance and servicing and minimum cost. Depending on the number of controlled points, it is apparently advisable to distinguish between centralized-control machines and group-control instruments. It is difficult to draw a clear cut boundary between the two but in practice, in analogy with existing multiple-point instruments, devices servicing up to 25 or 50 points are classified as group-control instruments.

The speed of the sampling device can be estimated from the speed of sampling, namely the number of points switched per unit time, and the sampling cycle, the time interval between two successive switchings to the same point.

It is necessary to distinguish here between the techni-

cally possible speed that can be insured by the machine and that speed which is technologically advisable.

If the statistical data obtained by operating a machine at a given object show that the parameters vary slowly, the number of deviations from specified limits is small, and their presence does not lead to dangerous consequences, it is advisable to reduce the speed of the machine and thereby increase its service life and the reliability of its operation.

The accuracy of the machine is determined essentially by the choice of the measurement scheme. The universally-used balancing circuits for measurement have made it possible, with suitable choice of their parameters, to insure a machine accuracy of the same order as obtained from modern electronic automatic instruments.

The problem of the reliability of operation of the control machine becomes particularly significant in connection with the use of a large number of inter-related elements: relays, vacuum tubes, step selectors, semiconductor elements, ferrites, etc.

In this case, unlike mathematical machines, machines for the control of manufacturing processes should strictly insure prolonged and continuous operation, since any stoppage of such a machine for several hours or even minutes can lead to a disturbance to the course of the technological process.

The reliability of the machines is increased by using the most reliable elements and by gradual changeover to contactless systems, by development of self-control circuits with rapid detection of irregularities, and also by constructing the machine in the form of a set of standardized interchangeable interacting functional blocks connected, by means of plugs, into a common system, and permitting rapid interchangeability.

The purpose of this article is not to classify the basic possible schemes for the construction of electronic machines for centralized control, but merely to acquaint the readers with one of the trends, adopted in the Independent-Construction-Technological Bureau for Biophysical Apparatus (SKTB-BFA) in the development of the machine MARS-300. (Machine for Automatic Registration and Signalization of technological processes with 300 points (MARS-300) )

The first completed model of this machine is intended for use in a synthetic rubber plant, and in the future similar machines are proposed for use in other plants of the chemical industry.

The MARS-300 machine (Fig. 1) controls 300 points at which temperature, average temperature, flow, and vacuum are measured.

The maximum speed of the sampling device for the detection of deviations is 10 points/second, i.e., all 300 points are scanned within 30 seconds.

In this case the technical speed of registration amounts to three seconds for each single point.

The commutation system is of the single-circuit type, i.e., when a deviation is detected, the sampling is interrupted during the time that the deviating parameter is recorded.

The machine yields information in numerical form and in the form of signals on a mimic bus.

The numerical information is printed on special charts called either registration charts for the deviations of the technological processes or charts for periodic registration of technological processes.

The values of the parameters that deviate from the preset range are printed in red on the "deviation chart," with indication of the time of deviation and the number of the deviating points. The parameters are printed in black after their return to the normal value, also with indication of the number of the point and of the time of return.

Recorded on the same chart is any of the control parameters, at the call of the operator.

At any instant of time, the operator can survey all the deviating parameters by successively recording them. In order to represent the fact that this is a deliberate call or survey of the deviations, they are recorded with a special symbol. The deviation card is the operating document for the running of the process.

On the periodic-registration card are printed the values of the parameters in specified time interval, 15 or 30

minutes, or one or two hours. A special column is earmarked for each recorded point.

The values of the parameters that deviate from the norm are printed in red. As a rule, the periodically recorded parameters are grouped by technological features, which makes it possible for the technologists to determine, by analyzing the charts, the mutual relationships between the values of the parameters, and to improve the technological process.

It is possible to record periodically either all the control points or a portion of them, depending on the requirements of the object. In the actual model of the machine, 50 out of the 300 points are recorded periodically.

When a deviation is observed, a suitable signal is shown on the mimic bus.

A simplified block diagram of the MARS-300 machine is shown in Fig. 2.

A triggering pulse from a clockwork mechanism is fed into the control blocks and triggers the pulse generator, which, in turn, sends to the control block a series of program pulses, effecting the automatic self-verification of the fundamental blocks and circuits of the machine in accordance with a specified program.

In the absence of irregularities, the control block produces a pulse that connects the machine for the cycle of periodic recording or for the recording of the deviations.

The printing device for periodic registration prints the verification symbol and the time of start of the periodic registration.

Next to be connected are the local commutators of the transducers, made up of step selectors with palladium-coated contacts. These commutators cause sequential switching of the transducers through the contacts of the transducer relays.

The commutator stops at each registered point and connects through the switching relay PR, the corresponding transducers to the standard measuring circuit. This circuit comprises a phase-sensitive unbalance amplifier (UFM) and a balancing motor M, which effects compensation of the transducer signal

by rotating the slider of a compensation rheostat or by moving the core of an induction coil, simultaneously turning the coated disk of numerical converter TsP through a definite combination of current-conducting and isolating paths on the surface of the disk of the numerical converter, under the contact of the brush assembly.

A special code is transmitted from the brush assembly to a relay decoder, for transformation into the necessary combination of the relay contacts, which connect the solenoids of the printing machine. All basic elements of the measurement circuits and of the circuit for numerical conversion are based on the standard units of the EPV instrument for thermocouples and the EPVI instrument for differential-transformer transducers.

The deviations are observed continuously or through a specified time interval. In this case there is a synchronous switching of the local transducer commutators (MKD) and of the stopping commutators (KU), which connect, through the contacts of the switching relays (PR), the transducers and the corresponding settings to the phase-sensitive amplifiers with relay outputs (UFR).

Upon detection of a deviation, the signal from the UFR goes to the control circuit, which stops the sampling and connects, by means of the contacts of the PR, the deviating transducers to the circuit described above, consisting of a measuring network, a numerical transformer of the decoder, and the printing device PU; the latter records in red the time, number and the value of the deviating point.

Simultaneously, the programming and control blocks (BTU) send a signal to the numbering device (ZU), where the deviating point is remembered by the corresponding relay, which then seals in. A signal to the mimic bus is sent from the contacts of this relay.

The sampling cycle is then resumed.

When the commutator passes again over a point that has previously shown to have a deviation, this part is no longer recorded until it is demonstrated that it has returned to normal. In the latter case, a special logical circuit in the BTU, which takes cognizance of the presence of a deviation in the ND, produces a signal for registration of the time, the number of the point, and its value, using black ink.

The machine is constructed in the form of a stand measuring 2000 x 2000 x 600 mm, having a number of cells. In these cells are inserted, along guides, functional blocks which are connected by means of plug disconnects to the general circuit.

The bulk of the blocks are relay blocks, blocks for step selectors, and for the unbalance amplifiers (Figs. 3, 4, and 5).

There are certain grounds for calling the MARS-300 machine a relay machine, for relays are used in it to switch the circuits of the transducers and the settings, to remember the deviating points, and to program and control the entire machine. Step selectors are used to switch the transducer relays and the setting relays, and also in the synchronism control and in the clockwork mechanism.

The electronic amplifiers are based on standard circuits used in electronic automatic instruments.

To get a better idea of the construction of the machine, we list below its principal elements and indicate their number in the entire machine and per single measurement point.,

| Name of Principal Element of Machine | Number of items in entire machine | Number of items per measurement point |
|--------------------------------------|-----------------------------------|---------------------------------------|
| Relays                               | 780*                              | 2.6                                   |
| Step Selectors                       | 35*                               | 0.11                                  |
| Vacuum tubes                         | 26                                | 0.09                                  |
| Germanium diodes                     | 600                               | 2.0                                   |
| Resistors                            | 2000                              | 6.7                                   |
| Capacitors                           | 200                               | 0.66                                  |

\* Includes the elements contained in the local blocks.

It is clear from the above that there are much fewer elements for each single measurement point in the control machine than would be used in the case of individual or multiple-point electronic automatic instruments. Consequently if a large number of control instruments is replaced by electronic machines, a great economy can be accomplished.

The printing devices used in the MARS-300 machines can be either modified electric-digital counting machines or automatic billing machines. Since the industry has so far not produced printing machines with zonal printing, it becomes necessary to use two printing devices respectively for the periodic recording and for the recording of the deviations.

The use of local blocks is due to the tendency to reduce the number of communications from the transducers to the machine, which in any given object turns out to be quite important, owing to the dispersion of the measuring points over a large area. Local blocks, each serving 50 measuring points, connect, as can be seen from the block diagram of the MARS-300 machines, the relays of the transducers and the local commutators based on step selectors. The machine is designed for use with 220 v ac. The average power consumed is approximately 250 watts.

Machines of the MARS type are designed for joint operation with standard transducers in the form of thermocouples, resistance thermometers, differential-transformer transducers, and rheostatic voltage transducers. This circumstance makes it possible to employ the MARS machine exclusively in manufacture without waiting for the development of a series of converters to change the transducer signals into quantities corresponding to the standard range of variation of the voltage, for example from C to 10 or 0 to 25 v dc. At the same time, a rapid development of such converters on the part of industry will permit substantial simplification in the control machines, facilitate their standardization and expand their range of application.

At the present time it is necessary to provide a specialized measuring circuit for each type of transducer. Thus, the MARS-300 machine contains two measuring systems, one for thermocouples and the other for the differential transformer transducers for flow and vacuum (only one measuring system is shown for the sake of simplicity in the block diagram).

The variety of requirements that are imposed on the machines by the operating conditions has already determined the large amount of possible schemes for the construction of centralized control systems and for their constructions, requiring generalization and experimental verification.

It must be said that, in addition to monitoring, machines of the MARS type perform many other control and regulation

functions. These functions include the switching of units on and off, damage control, and position regulation.

The use of machines with such control and regulation makes it possible to automatize fully the process of maintaining the temperature conditions and to observe the time of treatment necessary for the forming of rubber, plastics, and other articles in the chemical industry.

In this case the economic effect, according to preliminary calculations, amounts to not less than five million of rubles per year with expenses for automatization up to two million rubles, for one Moscow rubber-goods plant alone.

Any further improvement in the machines of the type MARS will obviously follow the line of increasing their speed, gradual changeover to contactless elements in the form of ferrite memories, ferro-transistor circuits of contactless commutators, and also along the development of more complicated forms of centralized regulation.

Taking into account the great national-economic significance of electric machines of centralized control and regulation, it is necessary to expand considerably the scientific research, design, and manufacturing base of this leading and promising region so that in the nearest years the electronic machines will find wide application in the chemical, petroleum, metallurgical, and other leading branches of the industry.

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| Date.....1958 |    |     |     |     |    |     |     |     |    |     |     |     | Chart for Recording Deviations of<br>Technological Processes of Controlled Shop |     |     |  | Shift No _____ |  |
|---------------|----|-----|-----|-----|----|-----|-----|-----|----|-----|-----|-----|---|-----|-----|--|----------------|--|
|               |    |     |     |     |    |     |     |     |    |     |     |     | [Part One]  |     |     |  |                |  |
| 12            | 10 | 110 | 360 | 12  | 10 | 216 | 340 | 12  | 10 | 321 | 365 | 12  | 10  | 324 | 370 |  |                |  |
| 12            | 20 | 105 | 377 | 12  | 20 | 107 | 349 | 12  | 20 | 110 | 355 | 12  | 20  | 112 | 338 |  |                |  |
| 12            | 20 | 326 | 360 | *12 | 20 | 649 | 100 | 12  | 30 | 101 | 333 | 12  | 30  | 105 | 370 |  |                |  |
| 12            | 30 | 529 | 345 | 12  | 30 | 640 | 360 | *12 | 30 | 649 |     |     |   |     |     |  |                |  |
| [Part Two]    |    |     |     |     |    |     |     |     |    |     |     |     |   |     |     |  |                |  |
| 12            | 10 | 528 | 380 | 12  | 10 | 640 | 366 | 12  | 10 | 644 | 324 | *12 | 10  | 649 | 100 |  |                |  |
| 12            | 20 | 216 | 335 | 12  | 20 | 221 | 365 | 12  | 20 | 324 | 365 | 12  | 20  | 425 | 322 |  |                |  |
| 12            | 30 | 106 | 346 | 12  | 30 | 221 | 360 | 12  | 30 | 326 | 344 | 12  | 30  | 528 | 370 |  |                |  |

Remark: Italic numbers are recorded in red in the machines.

| Date.....                     |     |                    |                    |                    |                    |                    |       |      |                    |                    |                    |                    | Chart for Periodic Recording of Technolog-<br>ical Processes of Controlled Shop |       |      |  | Shift No _____ |  |
|-------------------------------|-----|--------------------|--------------------|--------------------|--------------------|--------------------|-------|------|--------------------|--------------------|--------------------|--------------------|---|-------|------|--|----------------|--|
|                               |     |                    |                    |                    |                    |                    |       |      |                    |                    |                    |                    | [Part One]  |       |      |  |                |  |
| Number<br>of<br>furnace       |     | 1                  |                    |                    |                    |                    |       | 2    |                    |                    |                    |                    |   |       |      |  |                |  |
| No of<br>points               |     | 1                  | 18                 | 27                 | 44                 | 45                 | 49    | 50   | 1                  | 18                 | 27                 | 44                 | 45  | 49    | 50   |  |                |  |
| Meas-<br>ure-<br>ment<br>unit |     | $^{\circ}\text{C}$ | $^{\circ}\text{C}$ | $^{\circ}\text{C}$ | $^{\circ}\text{C}$ | $^{\circ}\text{C}$ | kg/hr | mm   | $^{\circ}\text{C}$ | $^{\circ}\text{C}$ | $^{\circ}\text{C}$ | $^{\circ}\text{C}$ | $^{\circ}\text{C}$  | kg/hr | mm   |  |                |  |
| Nominal                       |     |                    |                    |                    |                    |                    |       | Hg   |                    |                    |                    |                    |   |       | Hg   |  |                |  |
| Tolerance<br>ver-<br>if time  |     | +2                 | +5                 | +2                 | +5                 | +10                | +1.5  | +1.0 | +2                 | +5                 | +2                 | +5                 | +10   | +1.5  | +1.0 |  |                |  |
| *12 00                        | 330 | 350                | 365                | 330                | 360                | 100                | 08    | 334  | 350                | 365                | 330                | 345                | 100   | 08    |      |  |                |  |
| *13 00                        | 330 | 350                | 368                | 330                | 345                | 100                | 08    | 350  | 350                | 365                | 324                | 345                | 100   | 08    |      |  |                |  |
| *14 00                        | 333 | 350                | 365                | 330                | 345                | 100                | 08    | 330  | 344                | 365                | 330                | 345                | 100   | 08    |      |  |                |  |

## Chart Contd.

| Number of<br>furnace  | 1   |     |     |     |     |       |          | 2   |     |     |     |     |       |          |
|-----------------------|-----|-----|-----|-----|-----|-------|----------|-----|-----|-----|-----|-----|-------|----------|
|                       | 1   | 18  | 27  | 44  | 45  | 49    | 50       | 1   | 18  | 27  | 44  | 45  | 49    | 50       |
| No of<br>points       | °C  | °C  | °C  | °C  | °C  | kg/hr | mm<br>Hg | °C  | °C  | °C  | °C  | °C  | kg/hr | mm<br>Hg |
| Measure-<br>ment unit |     |     |     |     |     |       |          |     |     |     |     |     |       |          |
| Nominal               |     |     |     |     |     |       |          |     |     |     |     |     |       |          |
| Tolerance             | +2  | +5  | +2  | +5  | +10 | +1.5  | +1.0     | +2  | +5  | +2  | +5  | +10 | +1.5  | +1.0     |
| Verif. Time           |     |     |     |     |     |       |          |     |     |     |     |     |       |          |
| *15 00                | 330 | 342 | 365 | 330 | 345 | 100   | 08       | 330 | 350 | 365 | 330 | 360 | 100   | 08       |
| *16 00                | 330 | 350 | 365 | 330 | 345 | 100   | 06       | 330 | 350 | 361 | 330 | 345 | 100   | 08       |

## [Part Two]

| Number of<br>furnace | 3           |     |     |     |     |     |    | 4   |     |     |     |     |     |    |
|----------------------|-------------|-----|-----|-----|-----|-----|----|-----|-----|-----|-----|-----|-----|----|
|                      | Verif. Time |     |     |     |     |     |    |     |     |     |     |     |     |    |
| *12 00               | 330         | 350 | 365 | 330 | 345 | 102 | 08 | 330 | 350 | 368 | 330 | 345 | 100 | 08 |
| *13 00               | 330         | 356 | 365 | 330 | 345 | 100 | 08 | 330 | 350 | 365 | 330 | 345 | 100 | 06 |
| *14 00               | 330         | 350 | 365 | 322 | 345 | 100 | 08 | 330 | 357 | 365 | 330 | 345 | 100 | 08 |
| *15 00               | 326         | 350 | 365 | 330 | 345 | 100 | 08 | 330 | 350 | 365 | 330 | 345 | 102 | 08 |
| *16 00               | 330         | 350 | 369 | 330 | 345 | 100 | 08 | 338 | 350 | 365 | 330 | 345 | 100 | 08 |

## [Part Three]

| Number of<br>furnace | 5           |     |     |     |     |     |    | 6   |     |     |     |     |     |    |
|----------------------|-------------|-----|-----|-----|-----|-----|----|-----|-----|-----|-----|-----|-----|----|
|                      | Verif. Time |     |     |     |     |     |    |     |     |     |     |     |     |    |
| *12 00               | 327         | 350 | 365 | 330 | 345 | 100 | 08 | 330 | 350 | 365 | 324 | 345 | 100 | 08 |
| *13 00               | 330         | 350 | 365 | 330 | 332 | 100 | 08 | 330 | 357 | 365 | 330 | 345 | 100 | 08 |
| *14 00               | 330         | 343 | 365 | 330 | 345 | 100 | 08 | 326 | 350 | 365 | 330 | 345 | 100 | 08 |
| *15 00               | 330         | 350 | 368 | 330 | 345 | 100 | 08 | 330 | 350 | 362 | 330 | 345 | 100 | 08 |
| *16 00               | 330         | 350 | 365 | 340 | 345 | 100 | 08 | 330 | 350 | 365 | 330 | 360 | 100 | 08 |

Remarks: Numbers shown in italics are recorded in machine with red ink.

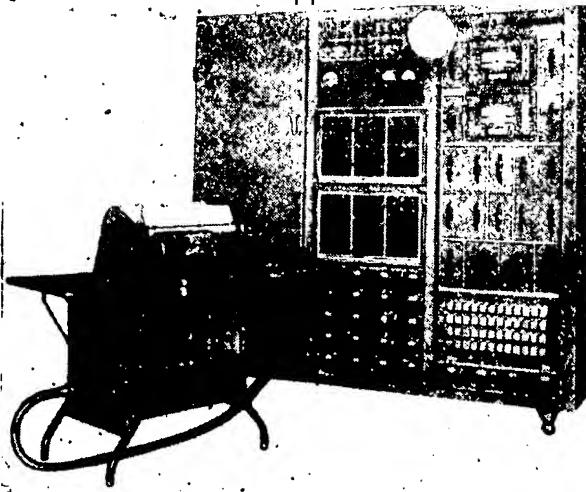


Fig. 1 MARS-300 Machine for recording and signalization of technological processes at 300 points of measurement of temperature, flow, and vacuum

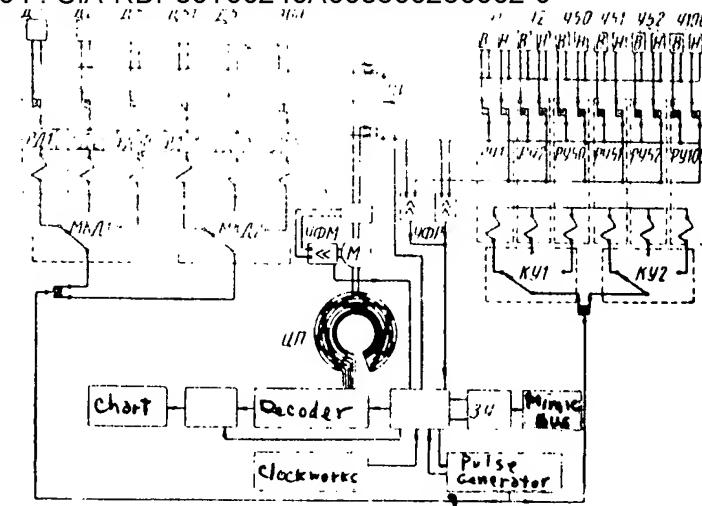


Fig. 2. Simplified Block Diagram of MARS-300 Machine: D<sub>1</sub>..D<sub>100</sub>—Transducers; R<sub>D</sub>1..R<sub>D</sub><sub>100</sub>—Relay Transducers; R<sub>U</sub>1..R<sub>U</sub><sub>100</sub>—Relay Settings. Other designations are denoted in text

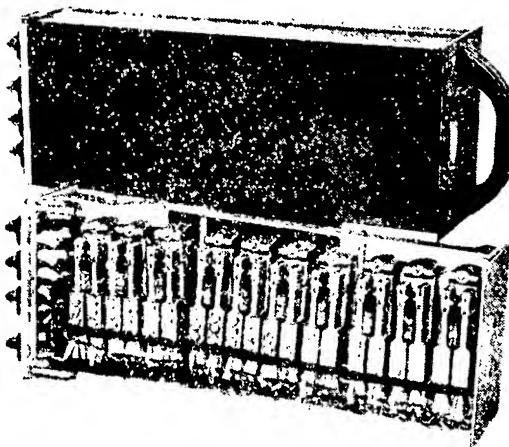


Fig. 3 Relay Block

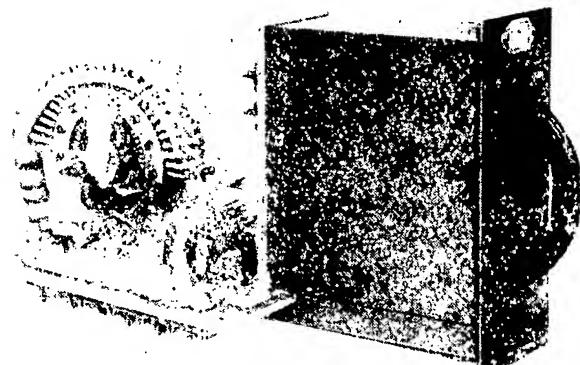


Fig. 4 Step-Selector Block

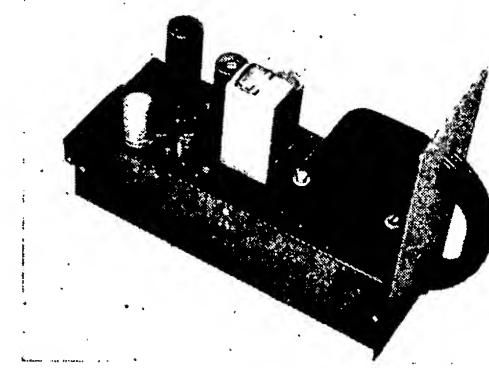
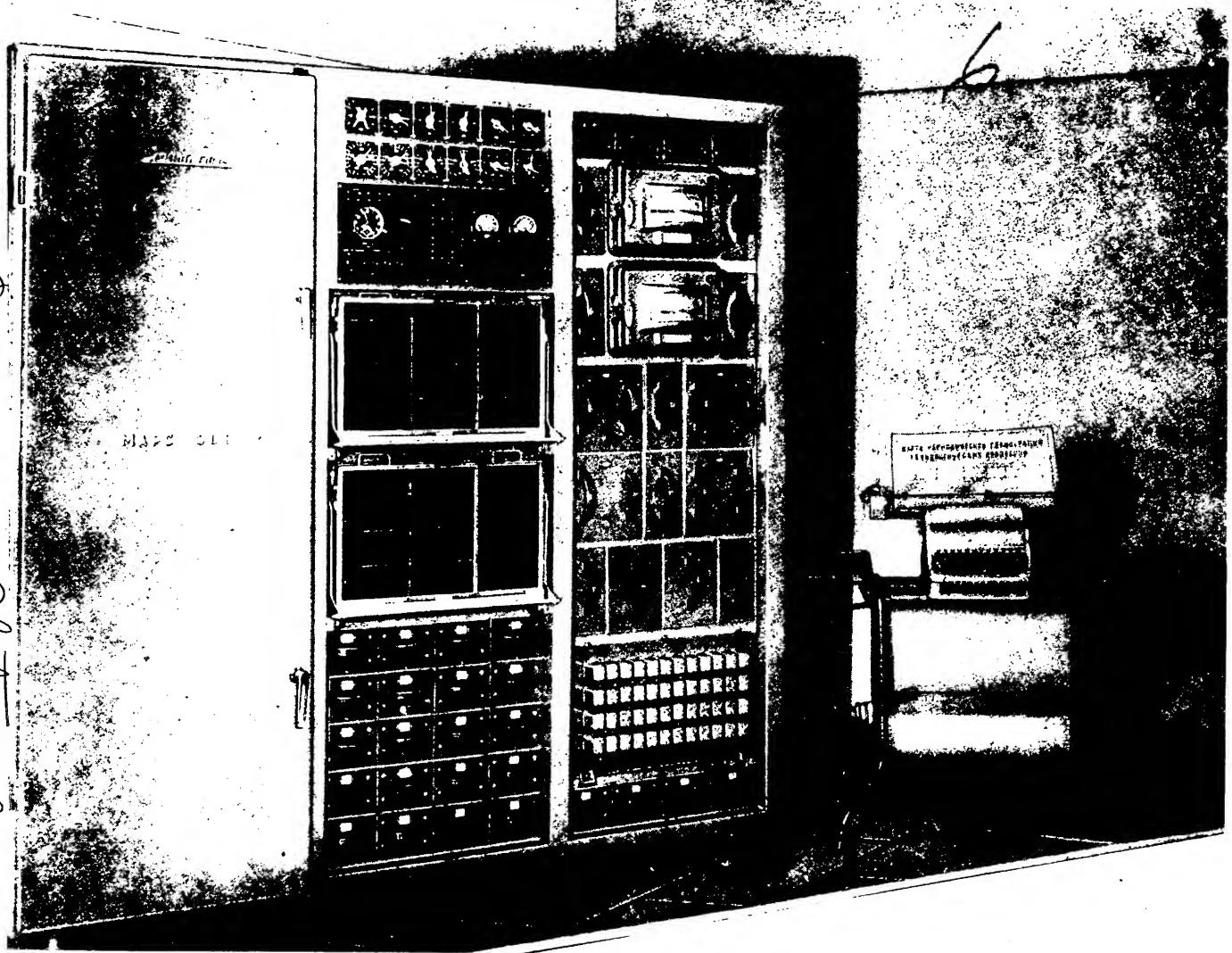


Fig. 5. Electronic amplifier

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